Economics of Fall Tillage for Early and Conventional Soybean Plantings in the Midsouthern USA

Larry G. Heatherly* and Stan R. Spurlock

ABSTRACT

Conventional soybean [*Glycine max* (L.) Merr.] production in the midsouthern USA has involved planting Maturity Group (MG) V and later cultivars in May and later months in a seedbed that has been shallow-tilled in the fall or spring just before planting. Moisture deficits that frequently occur from April through September reduce yield of soybean cultivars used in this traditional production system. Field experiments using MG IV 'DP 3478' and MG V 'Hutcheson' were conducted at Stoneville, MS (33°26′ N lat) on Sharkey clay (very fine, smectitic, thermic chromic Epiaquert) in 1995, 1996, and 1998. The objective was to compare yields and economic returns from April and May or later plantings of MG IV and V soybean cultivars grown without irrigation on clay soil following shallow (ST) and deep (DT) fall tillage. Net returns were calculated as the difference between income and all direct and indirect costs, excluding those for land, management, and general farm overhead. Costs for the DT treatment were \$22 to \$27 ha^{-1} greater than those for ST. Yields and net returns resulting from DT were greater than those from ST in 1 yr. Yields and net returns from April plantings were greater than those from May or later plantings in 2 of the 3 yr. These results indicate that April plantings will result in greater yields and net returns over the long term, but increased profits from DT are infrequent.

Conventional soybean production in the midsouthern USA utilizes MG V and later cultivars planted in May and later months in a seedbed that had been harrowed (disk or spring tooth) in the fall and left stale or untilled before planting (Heatherly and Elmore, 1983; Heatherly, 1999c) or harrowed in the spring just before planting. Use of this system resulted in an average yield of 1500 kg ha^{-1} during the 1970 through 1991 period in Mississippi (MCLRS, 1980, 1985; MASS, 1991, 1995; Anonymous, 1995).

The frequency and severity of moisture deficits at Stoneville, MS (33°26′N lat) typically increase from April through September (Boykin et al., 1995). Van Bavel (1959) calculated that the number of drought days (number of days in a period when potential evapotranspiration exceeds capacity of soil to supply that amount of water) in the middle Mississippi River valley was near zero in April and May but climbed to 13, 14, and 15 d mo^{-1} in June, July, and August, respectively. The effect of the drought days in July and August was compounded by previous months with a high incidence of drought. Cultivars planted in May or later typically flowered, set pods, and filled seeds during the hottest and driest portion of the growing season (Reicosky and Heatherly, 1990) when moisture deficits were greatest (Boykin et al., 1995) and soil water normally was depleted. Thus, they were susceptible to yield limitations imposed by drought. Results from research revealed that May and June plantings of these cultivars were high-risk enterprises (Heatherly, 1999a).

Planting early maturing cultivars (relative to latitude; MG IV and V at Stoneville, MS) in April vs. May and later allows their critical reproductive development to coincide with periods of adequate soil moisture and greater rainfall, thus partially avoiding drought stress. Recent reports indicate that a system involving seedbed preparation tillage in the fall; killing emerged weeds with a preplant, foliar-applied herbicide; and planting early maturing cultivars into a stale, untilled seedbed in April will result in improved yield and profit potential for soybean in the lower Mississippi River valley region (Heatherly, 1999b).

Kane and Grabau (1992) reported that MG II vs. traditional MG III, IV, and V soybean cultivars planted in late April or early May at Kentucky locations (36°40′ to 38°07′N lat) produced the highest average yields. Sweeney et al. (1995) showed that MG I soybean cultivars planted in April offer a viable alternative to traditional varieties of MG III, IV, and V planted in June in Kansas (37°20′N lat) dryland systems. Bowers (1995) conducted 3 yr (1986–1988) of nonirrigated studies at two northeast Texas locations (Blossom, 33°33′N lat and Hooks, 33°38′N lat) and found that MG III and IV cultivars planted in April yielded more than traditional MG V to VIII cultivars planted in May. Heatherly and Spurlock (1999) conducted a 5-yr study at Stoneville and found that yields of MG IV and V cultivars planted in April and not irrigated yielded more than nonirrigated May plantings and that net return from this system was higher. After 3 yr of research at St. Joseph, LA (31°50′N lat), Boquet (1998) concluded that consistent high yields produced by MG IV cultivars in a short-season system reduced risk of low yields or crop failure associated with the traditional system. Thus, it appears that higher yields can be obtained more consistently in the lower Mississippi River valley region by planting early maturing cultivars earlier in the spring than has been done. The reasons for higher yields associated with

L.G. Heatherly, USDA-ARS, Crop Genet. and Production Res. Unit, P.O. Box 343, Stoneville, MS 38776; and S.R. Spurlock, Dep. of Agric. Econ., Mississippi State, MS 39762. Received 24 Jan. 2000. *Corresponding author (lheatherly@ars.usda.gov).

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Abbreviations: DOP, date of planting; DT, deep fall tillage; FT, fall tillage; MG, maturity group; ST, shallow fall tillage.

this practice probably vary among locations; however, they must include drought avoidance and probably avoidance of above-optimum temperatures during reproductive phases. The advantage of earlier-than-normal planting is not realized at more northerly latitudes, as shown by Logan et al. (1998) at three Tennessee locations and by Steele and Grabau (1997) and Kane et al. (1997) at a Kentucky location. Reasons for this may be associated with low temperatures in April and lack of summer drought to the degree that it occurs in the lower Mississippi Valley region.

Clay soils occupy more than 3.7 million ha, or about 50% of the land area in the lower Mississippi River alluvial flood plain in the midsouthern USA. Of these clay soils, Sharkey is the dominant series and comprises about 1.2 million ha in the Mississippi River flood plain regions of Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee (Pettry and Switzer, 1996). Soybean is planted on the majority of the cropped clay soils, and most of this soybean hectarage is not irrigated. Thus, low yield potential, high-risk dryland production is the normal system (Heatherly, 1999a; Williams, 1999). Profitable production systems are needed for these nonirrigated sites.

If spring tillage is conducted, it almost always delays planting, and on poorly drained clay soils, that delay frequently becomes extended to weeks because of inconveniently timed spring rains. Heatherly (1981) measured almost identical yields among treatments in studies on Sharkey clay where deep tillage (0.45-m depth) performed in the spring (Mar., Apr., or May) was compared with shallow, disk-harrow spring tillage preceding soybean planting in May or later. Wesley and Smith (1991) performed deep tillage on a Tunica silty clay (clayey over loamy, smectitic, nonacid, thermic Vertic Haplaquept) in the fall following soybean harvest when the soil profile was dry as a result of soil water depletion in the growing season. They measured large, significant yield increases from soybean planted in May during years when drought occurred during the growing season and determined that net return was greatly increased from this practice (Wesley et al., 1994). The increased production was associated with increased moisture content in the soil, presumably because of greater infiltration and storage resulting from the deep tillage. This work has been used to promote the deep tillage of all dry clay soils in the fall.

Deep tillage of dry Sharkey clay soils in the fall has not been investigated as a production practice to be used with April planting. The objective of this work was to compare yields and economic returns from April and May or later plantings of MG IV and V soybean cultivars grown without irrigation on clay soil following shallow (ST) and deep (DT) fall tillage. Economic analysis of 3 yr of results was conducted to assess and compare the profitability of the two tillage systems in April vs. later plantings.

MATERIALS AND METHODS

Field studies were conducted in 1995, 1996, and 1998 on Sharkey clay at the Delta Research and Extension Center, Stoneville, MS (33°26′N lat). Each year, four adjacent nonirrigated experiments were conducted to encompass two dates of planting (DOP; DOP1, April; DOP2, May or June) of MG IV and V soybean cultivars following two fall tillage (FT) treatments (ST and DT). All experiments were conducted in a randomized complete block design with four replicates. All experimental units remained in the same location for the duration of the research. Effective deep tillage could not be done in the fall of 1996 because of wet soil resulting from 200 mm of rain that fell from 10 August through 30 September. Thus, results are not included from a 1997 experiment maintained on the same site.

On 28 Sept. 1994, 2 Oct. 1995, and 4 Oct. 1997, appropriate areas were either deep-tilled with an implement having curved tines spaced 1 m apart or shallow-tilled using a disk harrow and/or spring-tooth cultivator. All tillage operations were started immediately following harvest of soybean when soil was dry. Rainfall preceding deep tillage was 11 and 29 mm, respectively, in August and September 1994; 36 and 41 mm, respectively, in August and September 1995; and 71 and 56 mm, respectively, in August (before 15 Aug.) and September 1997. The deep tillage was done approximately 0.4 to 0.45 m deep and was followed by soil surface smoothing with a disk harrow and spring-tooth cultivator. Number of preplant tillage operations, implements used, and associated costs for ST and DT are shown in Table 1. Weather data in Table 2 were collected about 0.8 km from the experimental site by the Midsouth Agricultural Weather Service Center of the National Oceanic and Atmospheric Association in 1995 and by Delta Research and Extension Center personnel in 1996–1998.

Seed of DP 3478 (indeterminate MG IV cultivar) and Hutcheson (determinate MG V cultivar) were planted on 18 Apr. and 9 May 1995, 30 Apr. and 15 May 1996, and 9 Apr. and 10 June 1998. These cultivars were chosen because of their consistent high performance on a large hectarage in the region. Seed were treated before planting with metalaxyl [*N*-(2,6-dimethylphenyl)-*N*-(methoxyacetyl) alanine methyl ester] in 1995 and 1996 and with mefenoxam {(*R*)-[(2,6-dimethylphenyl)-methoxyacetyl-amino]-propionic acid methyl ester} in 1998 as a precaution against *Pythium* spp.

Row spacing was 0.5 m and seeding rate was 16 seed m^{-1} of row, or about 50 kg ha^{-1} seed. Plots were 30.5 m long and 4 m (eight rows) wide. Plantings were made into a stale seed-

Table 1. Number of trips and associated expenses under preplant tillage and total expenses for soybean planted on two dates in two fall tillage environments [shallow tillage (ST) and deep tillage (DT)] on Sharkey clay at Stoneville, MS, 1995–1998.

	ST			DT		
	Preplant tillage			Preplant tillage		
Planting date	No. trips†	Cost	Total	No. trips‡	Cost	Total
		— $ ha^{-1} —			— $ ha^{-1} —	
			1995			
18 Apr.	2	20	261	4	46	301
9 May	2	20	313	4	46	350
			1996			
30 Apr.	3	28	274	4	50	307
15 May	3	28	303	4	50	336
			1998			
9 Apr.	3	25	275	5	52	314
10 June	3	25	319	5	52	353

† Disk harrow in 1995; disk harrow and spring-tooth harrow (2) in 1996; and disk harrow, spring tooth harrow, and bedder in 1998.

‡ Subsoiler, disk harrow, and spring-tooth harrow (2) in 1995 and 1996; subsoiler, disk harrow, spring-tooth harrow, bedder, and spike-tooth harrow in 1998.

bed (Heatherly, 1999c) following application of glyphosate [*N*-(phosphonomethyl)glycine] to kill weed vegetation. After planting, weeds were managed every year with pre-emergent broadleaf and grass herbicides applied at labeled rates. In some years, broadleaf weeds emerged after planting and were controlled with postemergent herbicides that were applied at labeled rates and with appropriate adjuvants. Postemergent grass control was not needed in any year. In all cases, weeds were managed so that weed competition was not a factor limiting crop production.

All production inputs within each year were recorded for all experiments. Estimates of costs and returns were developed for each annual cycle of each experimental unit using the Mississippi State Budget Generator (Spurlock and Laughlin, 1992). Total specified expenses were calculated using actual inputs for each treatment in each year of the experiment and included all direct and fixed costs but excluded costs for land, management, and general farm overhead, which were assumed to be the same for all treatment combinations. Direct expenses included costs for pesticides, seed, and labor; costs for fuel, repair, and maintenance of machinery; cost of hauling harvested seed; and interest on operating capital. Fixed expenses were ownership costs for tractors, self-propelled harvesters, implements, and sprayers. Costs of variable inputs and machinery were based on prices paid by Mississippi farmers each year; i.e., machinery costs varied with year. Cost estimates of field operations were based on using 16-row equipment. Annual depreciation was calculated using the straight-line method with zero salvage value. Annual interest charges were based on one-half of the original investment times an appropriate interest rate for each year of the study.

Income from each experimental unit was calculated by multiplying the market-year average price for Mississippi (\$0.248, \$0.269, and \$0.222 kg^{-1} for 1995, 1996, and 1998, respectively) by the experimental yield. Yearly prices (MASS, 1999) were used instead of an average long-term price to reflect the effect of market forces on income for each individual year. Net returns above total specified expenses were determined for each experimental unit each year. Average price for the 1994–1998 period in Mississippi was \$0.240 kg^{-1}, which can be substituted for the yearly prices that were used in this presentation.

Soybean plant height at maturity was recorded for each plot just before harvest to determine the possible effect of tillage system on plant stature. A field combine modified for small plots was used to harvest the four center rows of each plot. Soybean seed were harvested from 28 Aug. to 28 Sept. 1995, 13 Sept. to 7 Oct. 1996, and 27 Aug. to 5 Oct. 1998. Yields were adjusted to 130 g moisture kg^{-1} seed.

Analysis of variance [PROC MIXED (SAS Inst., 1996)] was used to evaluate the significance of effects on plant height, seed yield, and net returns. Analyses across years treated year as a fixed effect to determine interactions involving year. Analyses for individual years treated FT and DOP as fixed effects and cultivar as random. Mean separation was achieved with an $LSD_{0.05}$.

RESULTS

Weather

In 1995, average maximum air temperatures were 2°C or more above normal in April, May, and August (Table 2). Moisture deficits (rainfall minus pan evaporation) in 1995 were above normal in May and August but below normal in July. The 15 July to 31 August period received only 25 mm of rain. Average maximum air temperatures in 1996 were near normal for most months. The months of June through August (reproductive period of both cultivars—Table 3) had near- or below-normal moisture deficits. In 1998, the May through August period was generally hotter than normal, and moisture deficits were above normal in all months except July. The 15 July to 31 August period received only 18 mm of rain. Thus, all years had periods of low rainfall and high temperatures that resulted in drought stress conditions during some portion of the soybean reproductive phase.

Table 2. Weather variables for indicated months and years at Stoneville, MS.

Month	Avg. max air temperature	Total rainfall (R)	Total pan evaporation (PE)	Difference (R − PE)
	°C	mm		
		30-yr normals†		
Apr.	23.4	136	154	−18
May	27.9	126	195	−69
June	31.9	95	216	−121
July	33.0	93	207	−114
Aug.	32.3	58	186	−128
		1995		
Apr.	25.6	244	–	–
May	29.9	79	202	−123
June	31.7	102	223	−121
July	32.8	148	214	−66
Aug.	35.0	36	219	−183
		1996		
Apr.	22.8	150	171	−21
May	31.1	62	269	−207
June	31.7	133	178	−45
July	32.8	84	201	−117
Aug.	31.7	110	162	−52
		1998		
Apr.	23.3	110	165	−55
May	30.6	117	208	−91
June	33.3	40	250	−210
July	34.4	145	198	−53
Aug.	34.4	18	192	−174

† 1964–1993 (Boykin et al., 1995).

Reproductive Development

Planting in April vs. May or later resulted in earlier dates for all reproductive stages (Fehr and Caviness,

Table 3. Dates of reproductive stages (Fehr and Caviness, 1977) of DP 3478 and Hutcheson soybean cultivars planted in April and May or June at Stoneville, MS, 1995–1998.

Planting date	Cultivar	Reproductive stage† R1	R3	R5	R6
		1995			
18 Apr.	DP 3478	29 May	19 June	10 July	10 Aug.
	Hutcheson	19 June	10 July	24 July	28 Aug.
9 May	DP 3478	16 June	3 July	28 July	24 Aug.
	Hutcheson	30 June	24 July	7 Aug.	1 Sept.
		1996			
30 Apr.	DP 3478	4 June	25 June	8 July	12 Aug.
	Hutcheson	21 June	12 July	22 July	26 Aug.
15 May	DP 3478	17 June	12 July	29 July	26 Aug.
	Hutcheson	5 July	26 July	12 Aug.	6 Sept.
		1998			
9 Apr.	DP 3478	26 May	22 June	10 July	10 Aug.
	Hutcheson	10 June	10 July	24 July	31 Aug.
10 June	DP 3478	10 July	31 July	14 Aug.	7 Sept.
	Hutcheson	24 July	10 Aug.	21 Aug.	21 Sept.

† R1, beginning bloom; R3, beginning pod; R5, beginning seed; R6, full seed.

Table 4. Seed yield from DP 3478 and Hutcheson soybean cultivars planted on two dates (DOP1 and DOP2) following two fall tillage (FT) treatments [shallow tillage (ST) and deep tillage (DT)] of Sharkey clay at Stoneville, MS, 1995–1998.

FT	DOP1†			DOP2‡			FT Avg.
	DP 3478	Hutcheson	Avg.	DP 3478	Hutcheson	Avg.	
	kg ha^{-1}						
				1995			
DT	2910	2400	2655	2040	1880	1960	2310
ST	2570	2280	2425	1970	1910	1940	2180
Avg.	2740	2340	2540	2005	1895	1950	
LSD(0.05)	FT = NS§; DOP = 311; Cultivar = 58; FT × DOP, FT × Cultivar, and DOP × Cultivar = NS						
				1996			
DT	2170	3040	2605	1950	3040	2495	2550
ST	1960	2500	2230	1690	2780	2235	2230
Avg.	2065	2770	2420	1820	2910	2365	
LSD(0.05)	FT = NS; DOP = NS; Cultivar = 115; FT × DOP, FT × Cultivar, and DOP × Cultivar = NS						
				1998			
DT	2550	1740	2145	810	990	900	1520
ST	1750	1260	1505	810	750	780	1140
Avg.	2150	1500	1825	810	870	840	
LSD(0.05)	FT = 166; DOP = 166; Cultivar = 64; FT × DOP = 235; FT × Cultivar = NS; DOP × Cultivar = 91/174¶						

† DOP1, 18 Apr. 1995, 30 Apr. 1996, and 9 Apr. 1998.
‡ DOP2, 9 May 1995, 15 May 1996, and 10 June 1998.
§ NS, not significant.
¶ First number is for comparing cultivar within same DOP; second number is for comparing same cultivar across DOPs.

1977) of both DP 3478 and Hutcheson (Table 3). DP 3478 planted in April reached R1 in late May to early June and R6 in early to mid-August. Hutcheson planted in April reached R1 in mid-June and R6 in late August. On the other hand, DP 3478 planted in May or early June reached R1 after mid-June and R6 in late August to early September. Hutcheson planted in May or early June reached R1 in late June or later and R6 in early to mid-September. Thus, April plantings of DP 3478 were at drought-susceptible reproductive stages about 1 mo or more earlier in the season than were May or June plantings of Hutcheson.

Costs

Costs within a planting date each year were essentially the same, except for those related to FT. Preplant tillage expenses and total expenses (excluding costs for land, management, and general farm overhead) for the ST and DT treatments within year and planting date are presented in Table 1. Costs associated with DT ranged from \$22 to \$27 ha^{-1} more than for ST. Differences in total cost between planting dates within a year were the result of greater weed control costs for the later planting. Differences in total cost among respective planting dates across years resulted from different weed control practices that were required to address each year's specific weed management requirements.

Plant Height

In 1995, DT resulted in an average plant height of 63 cm vs. an average of 56 cm for plants in ST (data not shown). Plants in DOP2 were 10 cm taller than those in DOP1, and DP 3478 plants averaged 17 cm taller than those of Hutcheson. In 1996, when the earlier planting was 30 April and the later planting was 15 May, DT resulted in only slightly taller plants than did ST (68 vs. 64 cm). Plants in DOP2 were 13 cm taller than those in DOP1, and DP 3478 plants averaged 16 cm taller than those of Hutcheson. In 1998, the 62-cm average height of DT plants was greater than the 51-cm average height of ST plants. Plants in DOP2 were 33 cm taller than plants in DOP1 while average height of DP 3478 plants was 16 cm greater than that of Hutcheson. Thus, in years when early planting occurred in early April, DT resulted in taller plants. Lodging greater than a few plants leaning did not occur in any year.

Seed Yield and Net Return

General

Analysis of variance revealed that interactions between year and all other factors were significant. Therefore, results are presented on an individual year basis.

1995

Average yields of 2180 and 2310 kg ha^{-1} from ST and DT, respectively, were not significantly different (Table 4). Average yield of 2540 kg ha^{-1} from DOP1 was greater than the 1950 kg ha^{-1} average yield from DOP2, and average yield from DP 3478 was greater than that from Hutcheson. Interactions among the three factors were not significant for yield.

The slightly higher (130 kg ha^{-1}) average yield from DT was not sufficient to offset the higher costs associated with DT (Table 1); thus, resultant average net returns from ST and DT were nearly identical at \$255 ha^{-1} and \$248 ha^{-1}, respectively (Table 5). Net return of \$350 ha^{-1} from DOP1 was greater than the \$152 ha^{-1} from DOP2. In DOP1, net return of \$390 ha^{-1} from DP 3478 was greater than the \$310 kg ha^{-1} net return from Hutcheson, while in DOP2, net returns from the two cultivars were similar. No other interactions were significant.

1996

Yield and net return were not significantly affected by either FT or DOP (Tables 4 and 5). Both average

Table 5. Net returns from DP 3478 and Hutcheson soybean cultivars planted on two dates (DOP1 and DOP2) following two fall tillage (FT) treatments [shallow tillage (ST) and deep tillage (DT)] of Sharkey clay at Stoneville, MS, 1995–1998.

FT	DOP1†			DOP2‡			FT
	DP 3478	Hutcheson	Avg.	DP 3478	Hutcheson	Avg.	Avg.
	$\$$ ha^{-1}						
				1995			
DT	411	306	358	149	125	137	248
ST	369	314	342	168	168	168	255
Avg.	390	310	350	158	146	152	
LSD(0.05)	FT = NS§; DOP = 75; Cultivar = 14; FT × DOP and FT × Cultivar = NS; DOP × Cultivar = 20/76¶						
				1996			
DT	276	517	396	189	485	337	367
ST	251	406	328	153	449	301	315
Avg.	264	462	362	171	467	319	
LSD(0.05)	FT = NS; DOP = NS; Cultivar = 30; FT × DOP, FT × Cultivar, and DOP × Cultivar = NS						
				1998			
DT	245	78	162	−179	−128	−154	4
ST	108	12	60	−144	−146	−145	−42
Avg.	176	45	111	−162	−137	−150	
LSD(0.05)	FT = 36; DOP = 36; Cultivar = 14; FT × DOP = 38; FT × Cultivar = NS; DOP × Cultivar = 20/38¶						

† DOP1, 18 Apr. 1995, 30 Apr. 1996, and 9 Apr. 1998.
‡ DOP2, 9 May 1995, 15 May 1996, and 10 June 1998.
§ NS, not significant.
¶ First number is for comparing different cultivars within same DOP; second number is for comparing same cultivar across DOPs.

yield and average net return from Hutcheson exceeded those from DP 3478. Interactions among the three factors were not significant for either yield or net return.

1998

Yield and net return were significantly affected by the FT × DOP and DOP × cultivar interactions (Tables 4 and 5). In DOP1, average yield following DT was 640 kg ha^{-1} greater than the average yield following ST, and average net return from DT was $\$102$ ha^{-1} greater than average net return from ST. In DOP2, average yield and net return from DT (1520 kg ha^{-1} and $\$4$ ha^{-1}) were not significantly greater than those from ST (1140 kg ha^{-1} and $\$-42$ ha^{-1}). DP 3478 outyielded Hutcheson in DOP1 but not in DOP2. Average net return from DP 3478 was greater than that from Hutcheson in DOP1 while the opposite was true in DOP2. In DOP1, the 2550 kg ha^{-1} yield from DT DP 3478 was the highest of any treatment combination. All net returns from DOP2 treatment combinations were negative.

DISCUSSION AND CONCLUSIONS

Levels of yield and net return achieved from deep tillage of the clay soil in this nonirrigated study did not approach those from irrigated plantings of soybean at this location (Heatherly and Spurlock, 1999). Also, these yield and net-return responses achieved as a result of DT of Sharkey clay are not of the magnitude of those achieved on Tunica silty clay by Wesley and Smith (1991) and Wesley et al. (1994). Presumably, the improved soil moisture status resulting from deep tillage that was measured by Wesley and Smith (1991) was not as effective for soybean grown on Sharkey clay in this study even though moisture deficits were experienced in all years. Rainfall amounts between DT dates and DOP1 dates in 1995, 1996, and 1998 were 900, 720, and 735 mm, respectively. These amounts were distributed over the approximate 6-mo period between FT and DOP1 dates in a manner that would have allowed a fully recharged soil profile at the beginning of each growing season.

The additional costs associated with deep tillage and subsequent seedbed preparation operations in this study were in the range of $\$22$ to $\$27$ ha^{-1}. Using the 1994–1998 average price of $\$0.24$ kg^{-1}, yield increases of 90 to 110 kg ha^{-1} would be required to break even. At a soybean price of $\$0.20$ kg^{-1}, a yield increase of 110 to 135 kg ha^{-1} would be necessary to break even. Thus, with low commodity prices, significant profitability from deep tillage of these clay soils in the fall will require larger yield increases than those obtained in this study. The significant yield increase obtained from the April planting in one year of this study provides a more positive outlook for increased profits if prices are higher than those used here. Thus, the use of DT on this soil should be based on expected commodity price because economical yield increases were not consistently achieved.

If equipment for deep tillage is on hand (fixed cost incurred), the occasional response of early planted cultivars to DT indicates that, over the long term, net return will be increased from DT. If equipment is not on hand, these results do not support the large capitalization required to obtain the necessary equipment. This practice should not be used for May and later plantings or to replace existing irrigation capability.

These results do not address the long-term effects of deep tillage of clay soil. The term of this study may not be long enough to determine if the effect of deep tillage of the clay soils is cumulative. The 1998 results can lead to this conclusion, but they may also just be the response to a unique set of weather conditions or to the earliest DOP1 date of the 3 yr. These results further confirm the importance of April planting of soybean cropped on nonirrigated clay hectarage in the midsouthern USA, regardless of FT input. Yields and net returns from the system used in this study were equal to or greater than those from the later plantings. Deep tillage in the fall complemented this system only in one year. Thus, the advantage of using deep tillage was not as consistent or pronounced as was the advantage (2 out of 3 yr) of using the early planting component.

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